

THE SIZE OF SPIDER EGGS AND ESTIMATES OF THEIR ENERGY CONTENT

John F. Anderson

Department of Zoology
University of Florida
Gainesville, Florida 32611 USA

ABSTRACT

Egg size was used to estimate the energy incorporated into egg production in a sample of 24 species representing 11 families. Egg mass scaled geometrically to egg diameter. Egg mass can be accurately estimated from the easily measured diameter of an egg. Comparison of egg sizes between populations of seven species common to Connecticut and Florida suggest egg size is species-specific. The constancy of energy density of spider eggs allows relatively accurate estimates of the energy incorporated into egg production using easily obtained data on egg size, number of eggs per clutch, and number of clutches.

INTRODUCTION

A basic consideration in most studies of spider reproduction relates egg production to energy availability (Craig 1987). In general, the number of clutches and number of eggs per clutch is determined by food supply (Bristowe 1958; Riechert and Tracy 1975; Enders 1976; Eberhard 1979; Craig 1987).

Studies emphasizing energetic costs of producing eggs exhibit a potential problem, namely the difficulty of measuring all the components necessary to estimate such costs. Single indices such as egg number (Petersen 1950; Enders 1976; Valerio 1976; Miyashita 1987a,b; Roach 1988; DeKeer and Maelfait 1988) and egg mass (Taylor and Peck 1975; Riechert and Tracy 1975; Killebrew and Ford 1985; Morse 1987) have been used as estimates of the energy incorporated into egg production. Use of single indices requires certain assumptions to make valid comparisons. For example, comparison of egg number assumes egg sizes are equal among the compared groups. A complete estimate of such costs over the life span of a female spider requires data on the number of clutches, the number of eggs per clutch, egg size, and energy density of the eggs. The fact that these studies are incomplete in this context is evidence of the very real difficulties of obtaining such data.

A major problem in this context is measurement of energy density. Accurate estimates using bomb calorimetry are time consuming and require skill, dedication, and careful attention to numerous procedural details (Phillipson 1964; Paine 1971; Anderson 1978). The time and labor involved justifies search of other methods of estimating relative energy content of eggs. Analysis of inter- and intraspecific variation of clutch size, egg size, and energy density indicate the

latter is the least variable (Anderson 1978). Killebrew and Ford (1985) argued that mass per newly hatched spiderling, and by extension, egg mass, in any one species is "optimized by natural selection." If correct, egg size might provide a practical and reasonably accurate measure of the energy content of a spider egg.

Here I evaluate egg size, measured as a linear dimension, to estimate egg mass. Linear dimensions of eggs can be easily and accurately measured using dissecting microscopes common to most laboratories. My specific aims were to determine whether egg size is species-specific and, if so, to describe the relationship between diameter and egg mass.

METHODS AND MATERIALS

Egg sacs of various species were collected from habitats around Gainesville, Florida. Although I picked species based on availability of reproductively active females, some effort was made to choose those which provide a reasonable range in the measured parameters. Of the 24 species considered here, data for 12 were obtained from a previous study (Anderson 1978).

Eggs were removed from egg sacs and counted. Their total wet mass was immediately measured to the nearest 0.1 mg and the average mass per egg determined by calculation. Egg diameter was measured to the nearest 0.01 mm with a dissecting microscope fitted with a calibrated ocular on a minimum of ten eggs per egg sac. Since few eggs are exactly spherical, the reported diameters represent the average of measurements made on the longest and the shortest axis of an egg. Differences between these two measurements of all samples averaged 7%.

Assuming geometric similarity obtains, i.e., shape and density are constant, the mass of an egg would be proportional to diameter³ where the latter represents a characteristic linear dimension (McMahon and Bonner 1983). Consequently I fitted the data to the power function $EM = aED^b$. Here EM represents egg wet mass; ED is egg diameter; a is a proportionality constant and b is the exponent of the function. The parameters a and b were calculated by least squares analysis of paired data after transformation to common logarithms. Correction for bias in log-transformed data (Sprugel 1983) made in estimating the proportionality constant (a) produced a result not different from the uncorrected value. The standard error (S_b) and 95% confidence limits for b , r^2 , and $Sy \cdot x$ were calculated as indices of fit of the regression as recommended by Smith (1984).

RESULTS AND DISCUSSION

The data collected from 24 species representing 11 spider families (Table 1) show much variation. The largest female is 112 times the smallest in the sample; number of eggs per clutch, egg diameter, and egg mass exhibit 39-, 2.8-, and 17.5-fold variation in these measures, respectively.

A good fit exists between egg mass and egg diameter (Fig. 1). The coefficient of determination (r^2) is 0.99 and indicates the fraction of variation in egg mass explained by variation in egg diameter. The standard error of the estimate ($Sy \cdot x$), standard error (S_b) and 95% confidence limits for b are 0.035, 0.066, and 2.77-3.05, respectively. Support for the predictive ability of the model is provided by

Table 1.—Number, size, and mass of spider eggs. Data are averages (+/- SD).

FAMILY Species	Sample size (clutches)	Female live mass (mg)	Number of eggs per clutch	Egg diameter (mm)	Egg live mass (mg)
FILISTATIDAE					
<i>Filistata hibernalis</i>	14	347 (188)	129 (63)	1.37 (0.05)	1.42 (0.01)
<i>Physocyclus</i> species	3	28.9 (8.0)	73 (9.2)	0.82 (0.01)	0.31 (0.03)
THERIDIIDAE					
<i>Achaearanea tepidariorum</i>	5	37.7 (19.3)	149 (55)	0.59 (0.01)	0.12 (0.01)
<i>Argyrodes trigonum</i>	2	10.9	42	0.67	0.17
<i>Tidarren sisypoides</i>	1	51.8	238	0.66	0.16
ARANEIDAE					
<i>Acanthepeira stellata</i>	2	596	574	1.04	0.55
<i>Acanthepeira venusta</i>	5	182 (72)	232 (70)	0.88 (0.02)	0.34 (0.02)
<i>Argiope aurantia</i>	2	752	978	0.92	0.46
<i>Gasteracantha elipsoides</i>	1	175	195	0.81	0.25
<i>Mecynogea lemniscata</i>	7	59.9 (11.1)	25 (5.3)	1.01 (0.01)	0.54 (0.04)
<i>Metazygia wittfeldae</i>	5	87.0 (29.9)	84 (31)	1.06 (0.07)	0.51 (0.08)
<i>Nuctenea cornuta</i>	5	263 (52)	484 (130)	1.00 (0.02)	0.49 (0.05)
AGELENIDAE					
<i>Agelenopsis barrowsi</i>	1	138	60	0.98	0.47
PISAURIDAE					
<i>Pisaurina mira</i>	3	293 (78)	264 (207)	1.15 (0.09)	0.78 (0.09)
LYCOSIDAE					
<i>Lycosa lenta</i>	6	1007 (234)	302 (48)	1.45 (0.05)	1.59 (0.15)
OXYOPIDAE					
<i>Peucetia viridans</i>	5	348 (22)	382 (36)	1.48 (0.02)	1.77 (0.08)
SPARASSIDAE					
<i>Heteropoda venatoria</i>	1	1221	184	1.66	2.10
THOMISIDAE					
<i>Misumenoides formosipes</i>	1	117	552	1.01	0.47
<i>Misumenops celer</i>	1	28.1	73	0.78	0.25
SALTICIDAE					
<i>Eris marginata</i>	1	43.1	59	0.93	0.37
<i>Phidippus audax</i>	4	223 (29.3)	186 (69)	1.26 (0.05)	1.03 (0.09)
<i>Phidippus pulcherrimus</i>	4	75.1 (9.0)	76 (15)	1.25 (0.01)	1.00 (0.08)
<i>Phidippus regius</i>	1	570	439	1.29	1.17
<i>Thiodina sylvana</i>	2	44.9	70	1.08	0.69

Wise's (1973) data on egg dimensions of *Linyphia marginata*. Given the reported diameter for these eggs, the equation (Fig. 1) predicts a wet weight equal to that indicated.

Although egg size exhibits much variation interspecifically (Table 1), I was impressed by the constancy of this measure within a species (see also Anderson 1978; Killebrew and Ford 1985). For example, the coefficients of variation involving egg diameter *within* each of the 12 species where multiple samples were available average 3.0% (Table 1). Conversely, the coefficient of variation for average egg diameter of the same 12 species is 24.3%. If egg size is species-dependent and not subject to environmental influences, egg sizes of the same species from different populations should not differ from one another. Such a comparison was made using the appropriate data from Kaston (1981) for Connecticut populations of seven species in common (Table 2). Analysis of the paired data indicate no significant differences exist ($P = 0.94$) in egg size. The

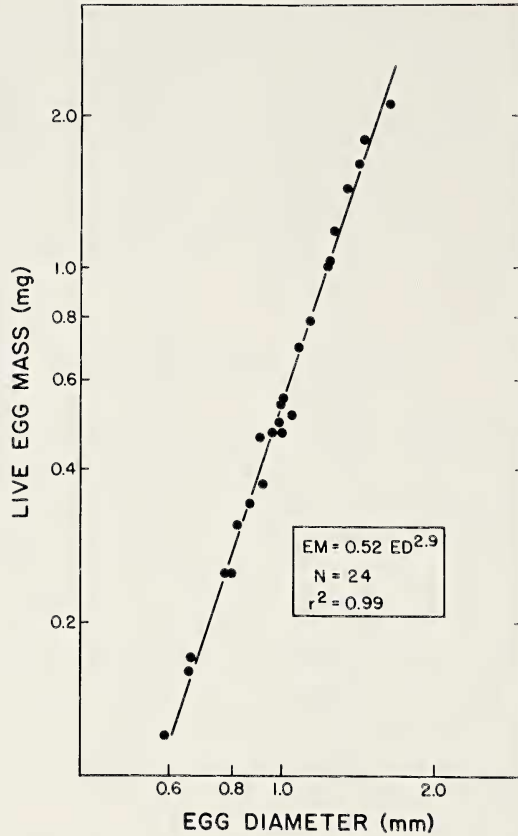


Figure 1.—Relationship between wet mass of egg (EM) and egg diameter (ED).

constancy of egg size provides validity to those studies comparing numbers of eggs or total egg mass as is so common in intraspecific studies.

The accuracy of estimates of the amount of energy incorporated into egg production made from number of clutches, number of eggs and their weight would depend on variation in energy density of eggs. Although variation in this measure is biologically significant and is correlated with the early life history patterns of individual species, the magnitude of this variation is not large (Anderson 1978). The reported values for the 12 species studied range from 26.3 to 29.0 joules per mg ash-free dry weight with an average of 27.3. Dry weight and

Table 2.—Comparison of egg size in spiders from Connecticut (Kaston 1981) and Florida (this study).

Species	Egg diameter (in mm)	
	Connecticut	Florida
<i>A. tepidariorum</i>	0.55	0.59
<i>A. trigonum</i>	0.65	0.67
<i>A. aurantia</i>	1.00	0.92
<i>N. cornuta</i>	1.00	1.15
<i>P. mira</i>	1.20	1.15
<i>M. formosipes</i>	0.96	1.01
<i>P. audax</i>	1.22	1.26

ash content of spider eggs are 31.9 and 3.58% of wet weight, respectively (Anderson 1978). Relative to the average, the potential error associated with the highest and lowest value are 6.2 and 3.7%, respectively. Since variation in the other variables such as number of clutches, number of eggs, and egg size is usually much larger, assuming a constant energy density would provide reasonably accurate comparative estimates of the energy incorporated into egg production in most cases. Certainly the number of egg sacs, number of eggs, and egg size can be counted and measured with ease and accuracy thus permitting more extensive studies of the energetics of reproductive output than would otherwise be practical.

ACKNOWLEDGMENTS

I wish to thank C. Binello and G. Kiltie for typing the manuscript, D. Harrison for aid in constructing the figure, and both reviewers for their constructive suggestions.

LITERATURE CITED

- Anderson, J. F. 1978. Energy content of spider eggs. *Oecologia*, 37:41-57.
- Bristowe, W. S. 1958. *The World of Spiders*. Collins, London.
- Craig, C. L. 1987. The significance of spider size to the diversification of spider-web architectures and spider reproductive modes. *American Natur.*, 129:47-68.
- DeKeer, R. and J. F. Maelfait. 1988. Laboratory observations on the development and reproduction of *Erigone atra* Blackwall, 1833 (Araneae, Linyphiidae). *Bull. British Arachnol. Soc.*, 7:237-242.
- Eberhard, W. G. 1979. Rates of egg production by tropical spiders in the field. *Biotropica*, 11:292-300.
- Enders, F. 1978. Clutch size related to hunting manner of spider species. *Ann. Entomol. Soc. America*, 69:991-998.
- Kaston, B. J. 1981. *Spiders of Connecticut*. 2nd ed. Connecticut State Geol. Natur. Hist. Survey. Bull. No. 70.
- Killebrew, D. W. and N. B. Ford. 1985. Reproductive tactics and female body size in the green lynx spider, *Peucetia viridans* (Araneae, Oxyopidae). *J. Arachnol.*, 13:375-382.
- McMahon, T. A. and J. T. Bonner. 1983. *On Size and Life*. Sci. American Books, New York.
- Miyashita, K. 1987a. Development and egg sac production of *Achaearanea tepidariorum* (C. L. Koch) (Araneae, Theridiidae) under long and short photoperiods. *J. Arachnol.*, 15:51-58.
- Miyashita, K. 1987b. Egg production of *Achaearanea tepidariorum* (C. L. Koch) (Araneae, Theridiidae) in the field in Japan. *J. Arachnol.*, 15:130-132.
- Morse, D. H. 1987. Attendance patterns, prey capture, changes in mass, and survival of crab spiders *Misumena vatia* (Araneae, Thomisidae) guarding their nests. *J. Arachnol.*, 15:193-204.
- Paine, R. T. 1971. The measurement and application of the calorie to ecological problems. *Ann. Rev. Ecol. System.*, 2:145-164.
- Petersen, B. 1950. The relation between size of mother and number of eggs and young in some spiders and its significance for the evolution of size. *Experientia*, 6:96-98.
- Phillipson, J. 1964. A miniature bomb calorimeter for small biological samples. *Oikos*, 15:130-139.
- Riechert, S. E. and C. R. Tracy. 1975. Thermal balance and prey availability: bases for a model relating web-site characteristics to spider reproductive success. *Ecology*, 56:265-284.
- Roach, S. H. 1988. Reproductive periods of *Phidippus* species (Araneae, Salticidae) in South Carolina. *J. Arachnol.*, 16:95-101.
- Smith, R. J. 1984. Allometric scaling in comparative biology: problems of concept and method. *American J. Physiol.*, 246:R152-R160.
- Sprugel, D. G. 1983. Correcting for bias in log-transformed allometric equations. *Ecology*, 64:209-210.
- Taylor, B. B. and W. B. Peck. 1975. A comparison of northern and southern forms of *Phidippus audax* (Hentz) (Araneida, Salticidae). *J. Arachnol.*, 2:89-99.

- Valerio, C. E. 1976. Egg production and frequency of oviposition in *Achaearanea tepidariorum* (Araneae, Theridiidae). Bull. British Arachnol. Soc., 3:194-198.
- Wise, D. H. 1973. Egg cocoon of the filmy dome spider *Linyphia marginata* C. L. Koch (Araneae: Linyphiidae). J. Arachnol., 1:143-144.

Manuscript received June 1989, revised September 1989.